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Damerau et al.

[45] Date of Patent: **Nov. 2, 1993****[54] METHOD AND APPARATUS FOR "WRONG WORD" SPELLING ERROR DETECTION AND CORRECTION**

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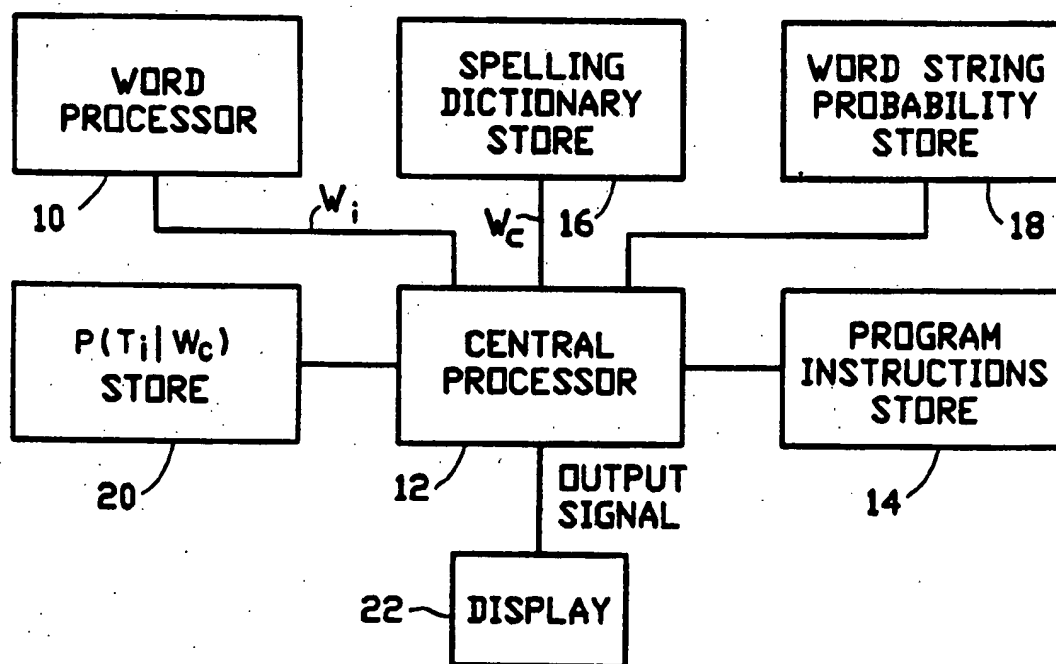
Attorney, Agent, or Firm—Marc D. Schechter

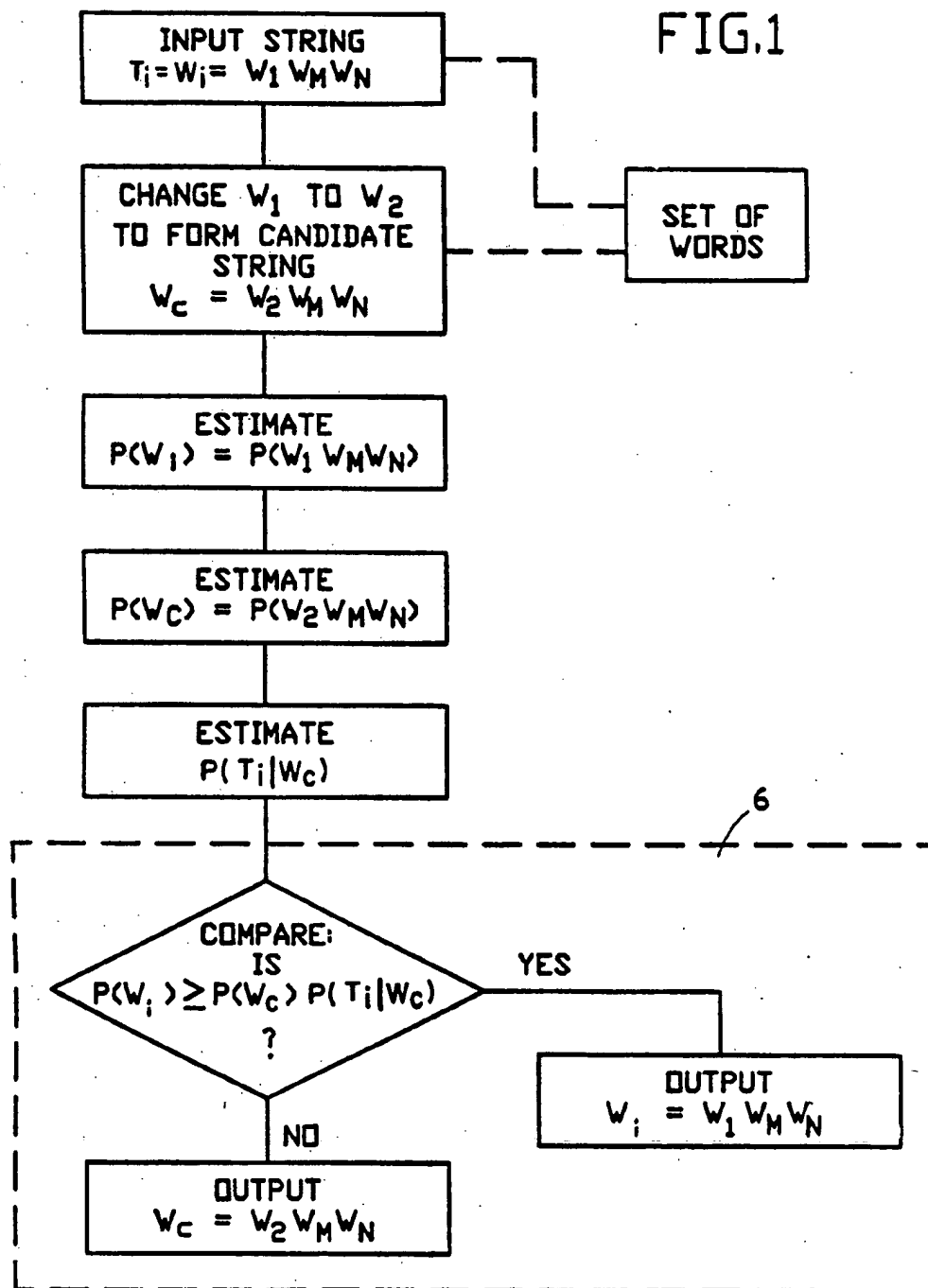
[57] ABSTRACT

A method of detecting and correcting an error in a string of information signals. When each information

signal represents a word, the method detects and corrects spelling errors. The method detects and corrects an error which is a properly spelled word, but which is the wrong (not intended) word. For example, the method is capable of detecting and correcting a misspelling of "HORSE" as "HOUSE". In the spelling error detection and correction method, a first word in an input string of words is changed to form a second word different from a first word to form a candidate string of words. The spellings of the first word and the second word are in the spelling dictionary. The probability of occurrence of the input string of words is compared to the product of the probability of occurrence of the candidate string of words multiplied by the probability of misrepresenting the candidate string of words as the input string of words. If the former is greater than or equal to the latter, no correction is made. If the former is less than the latter, the candidate string of words is selected as a spelling correction.

36 Claims, 5 Drawing Sheets





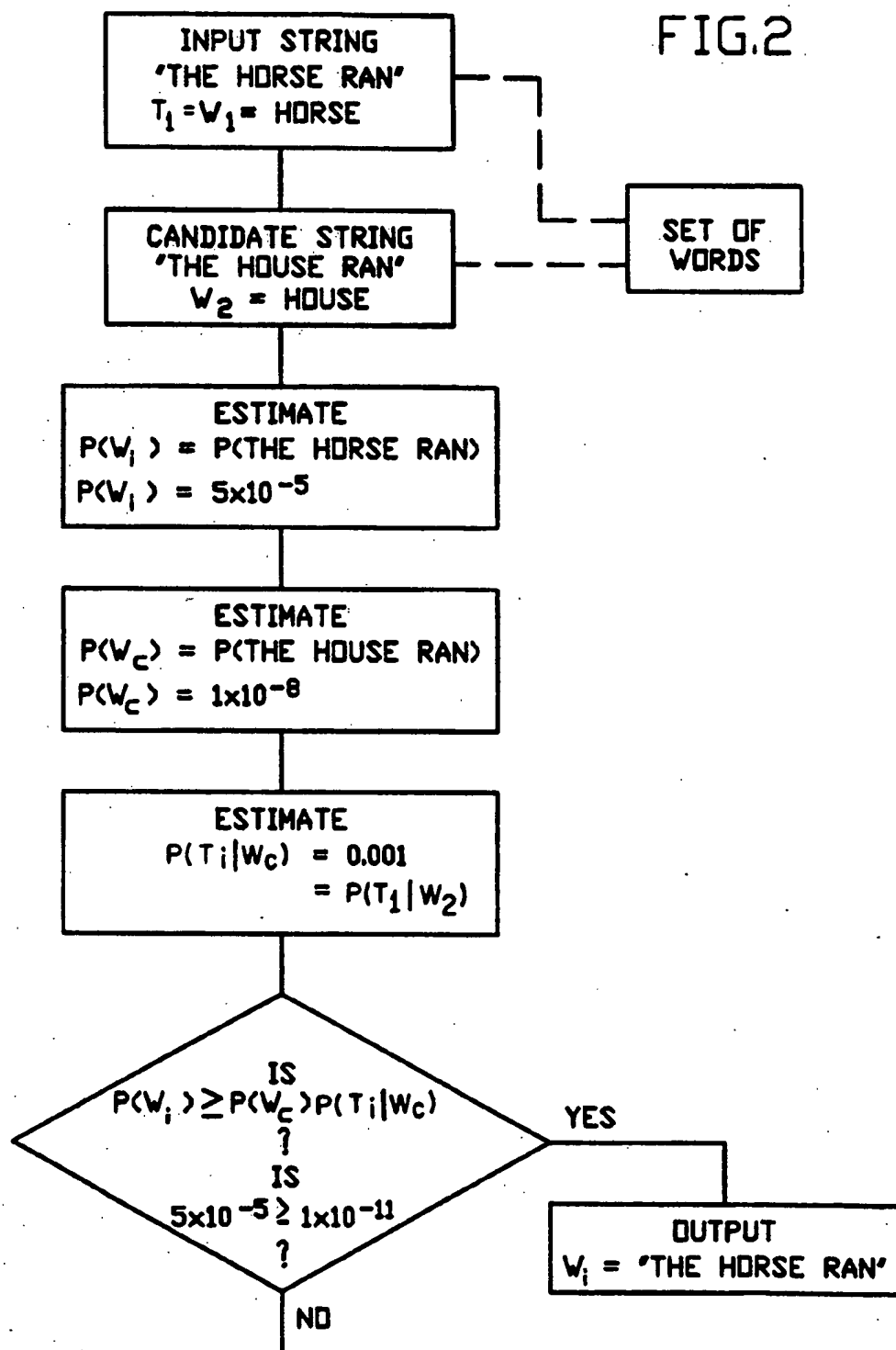
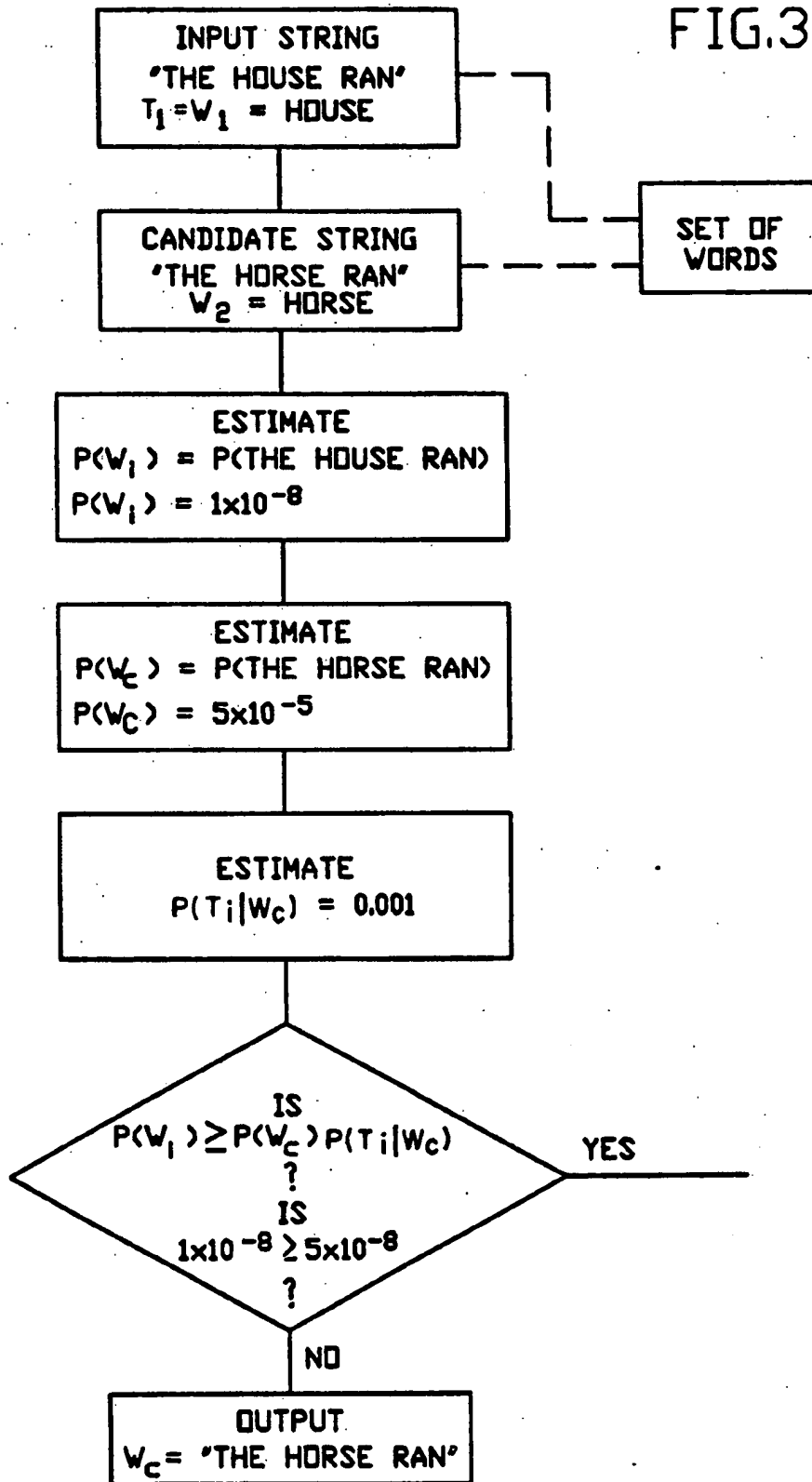


FIG. 3



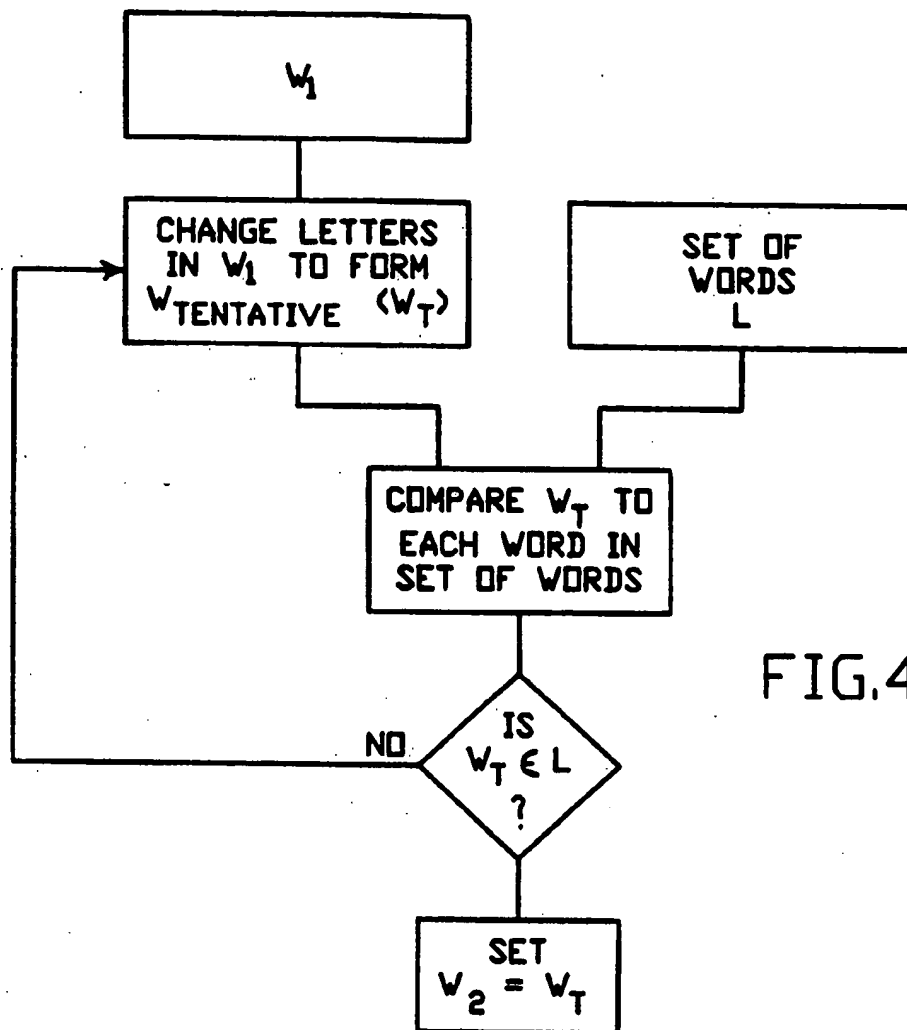


FIG. 4

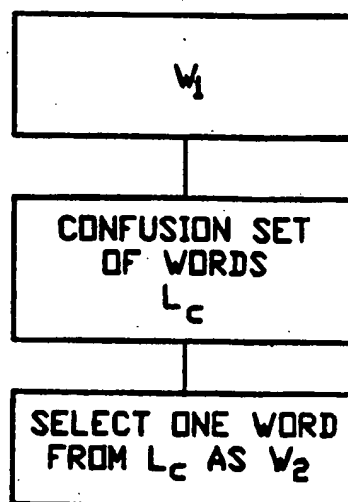
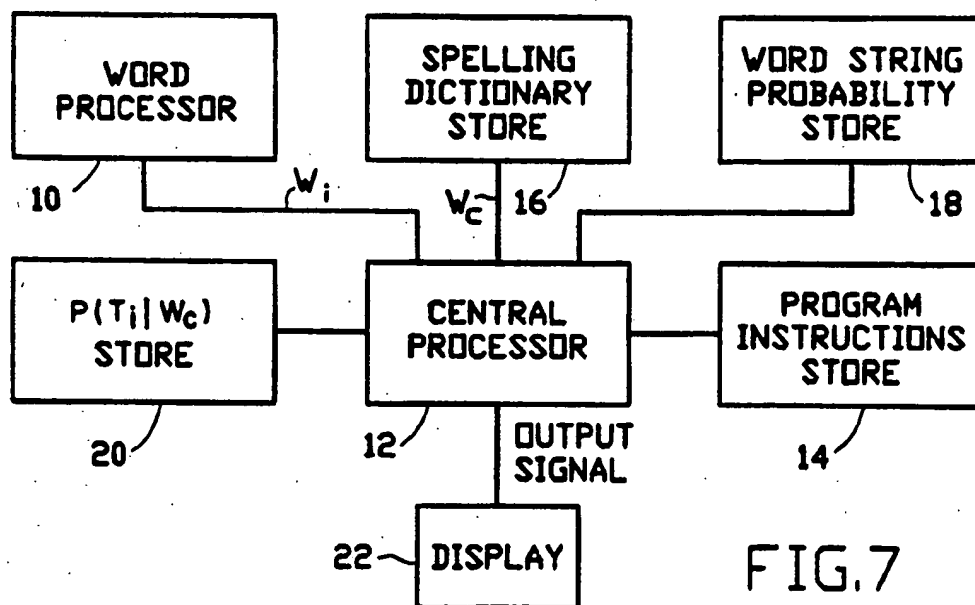
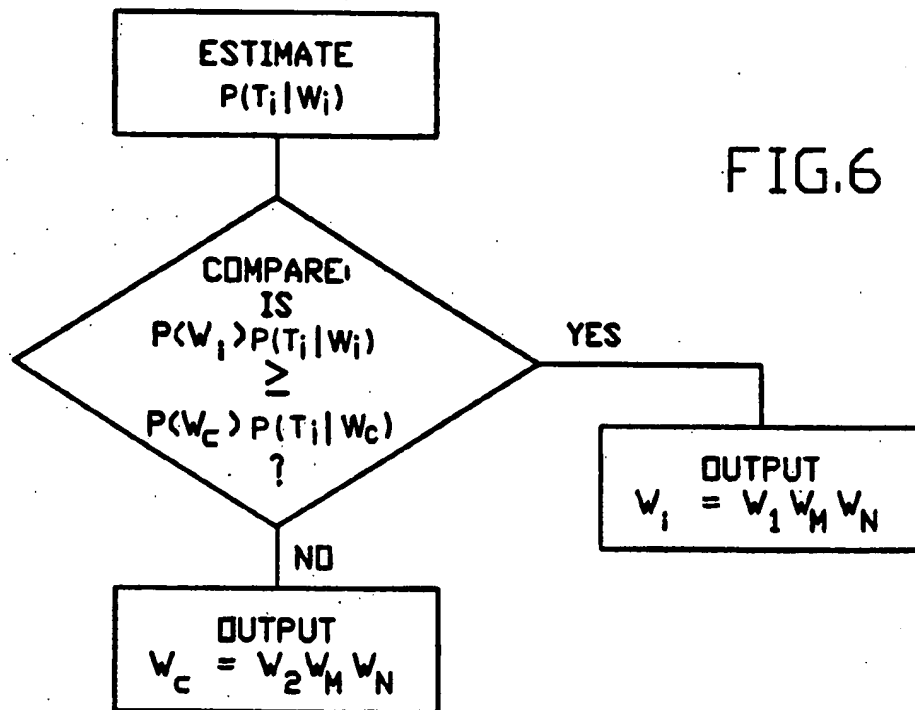


FIG. 5



METHOD AND APPARATUS FOR "WRONG WORD" SPELLING ERROR DETECTION AND CORRECTION

BACKGROUND OF THE INVENTION

The invention relates to methods and apparatus for detecting and correcting errors in information signals. More specifically, the invention relates to the detection and correction of spelling errors.

In text processing apparatus, such as dedicated word processors or word processing programs which are run on general purpose digital computers, it is desirable to provide automatic detection and correction of spelling errors. Most spelling error detection apparatus and programs check each word in a text against the entries in a spelling dictionary. Words in the text which are not found in the spelling dictionary are assumed to be misspelled. The misspelled words are identified to the text processing operator by, for example, highlighting the word on a display device. Sometimes candidate words having spellings similar to the misspelled word are also displayed to the operator as proposed corrections.

The known apparatus and methods for detecting and correcting spelling errors have several deficiencies. Most importantly, the known apparatus and methods cannot detect a "wrong word" erroneous spelling (where the erroneous spelling is itself a word in the spelling dictionary but is not the word that was intended).

Moreover, even where the erroneous spelling does not appear in the spelling dictionary, the prior apparatus and methods provide no means or only limited means for ranking alternative candidates for the correct spelling.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a method and apparatus for detecting and correcting an error in an information signal, where the information signal represents the wrong information. When the information signal represents a word, the invention provides a method and apparatus for detecting and correcting spelling errors, where erroneously spelled words are correct entries in the spelling dictionary, but are not the intended words.

It is another object of the invention to provide a method and apparatus for estimating the probability of occurrence of a word whose spelling is being checked, and to estimate the probabilities of one or more alternative words as candidates for replacing the word being checked.

In a spelling error detection and correction method according to the present invention, an input string of words $T_i = W_i$ is provided. The spelling of a first word $T_1 = W_1$ in the input string is changed to form a second word W_2 different from the first word, to form a candidate string of words W_c . The probability $P(W_i)$ of occurrence of the input string of words and the probability $P(W_c)$ of occurrence of the candidate string of words are estimated. The probability $P(T_i|W_c)$ of misrepresenting the candidate string of words W_c as the input string of words T_i is also estimated. Thereafter, $P(W_i)$ is compared with the product $P(W_c)P(T_i|W_c)$. A first output is produced if $P(W_i)$ is greater than $P(W_c)P(T_i|W_c)$, otherwise a second output is produced.

In one aspect of the invention, the first output comprises the input string of words. The second output,

comprises the candidate string of words. Alternatively, the second output may be an error indication.

The probability $P(T_i|W_c)$ of misrepresenting the candidate string of words as the input string of words may be estimated as the probability $P(T_1|W_2)$ of misspelling the second word W_2 as the first word T_1 .

In the spelling error detection and correction method and apparatus according to the invention, each word in the input string and each word in the candidate string is a member of a set of correctly spelled words.

Preferably, the method and apparatus according to the invention further comprise the step of estimating the probability $P(T_i|W_i)$ of correctly spelling all of the words in the input string of words W_i . In this case, the product $P(W_i)P(T_i|W_i)$ is compared with the product $P(W_c)P(T_i|W_c)$. The first output is produced if $P(W_i)P(T_i|W_i)$ is greater than $P(W_c)P(T_i|W_c)$, otherwise the second output is produced.

The probability $P(T_i|W_i)$ of correctly spelling all of the words in the input string may be estimated as the probability $P(T_1|W_1)$ of correctly spelling the first word W_1 .

According to an embodiment of the invention, the spelling of the first word T_1 may be changed to form the second word W_2 by adding, deleting, transposing, or replacing one or more letters in the first word to form a tentative word. The tentative word is compared to each word in the set of words. The tentative word is used as the second word W_2 if the tentative word matches a word in the set of correctly spelled words.

Alternatively, the spelling of the first word may be changed to form a second word by identifying a confusion group of M different words in the set of correctly spelled words. Each word in the confusion group may, for example, have a spelling which differs from the first word by no more than two letters. Alternatively, each word in the confusion group may be one which is confusable with the first word. At least one word in the confusion group is selected as the second word W_2 .

Satisfactory results have been obtained in the method and apparatus according to the invention by estimating the probability of correctly spelling a word as 0.999. The probability of misspelling a word may be estimated to be $(0.001/M)$.

The spelling error detection and correction method and apparatus according to the present invention are advantageous because by comparing the probability of occurrence of the word being checked and the probabilities of occurrence of one or more spelling correction candidates, it is possible to detect and correct errors which are correct spellings of the wrong word.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram of an embodiment of the spelling error detection and correction method according to the present invention.

FIG. 2 is a block diagram of an example of the spelling error detection and correction method of FIG. 1.

FIG. 3 is a block diagram of another example of the spelling error detection and correction method of FIG. 1.

FIG. 4 is a block diagram of an embodiment of a routine for changing the spelling of a first word to form a second word in the spelling error detection and correction method according to the present invention.

FIG. 5 is a block diagram of an alternative embodiment of a method of changing the spelling of a first word to form a second word.

FIG. 6 is a block diagram of a preferred modification of the spelling error detection and correction method shown in FIG. 1.

FIG. 7 is a block diagram of an embodiment of an apparatus for detecting and correcting an error in an information signal.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is a method of detecting and correcting an error in an information signal. In the case where each information signal represents a word which is a member of a set of correctly spelled words, the invention provides a method of spelling error detection and correction.

Referring to FIG. 1, the spelling error detection and correction method starts with the step of providing an input string of words $T_1 = W_i$. Each word in the input string has a spelling.

Next, the spelling of a first word $T_1 = W_2$ in the input string is changed to form a second word W_2 different from the first word, to form a candidate string of words W_c .

In FIG. 1, the input string and the candidate string each comprise three words. According to the invention, the input and candidate strings may be any length greater than or equal to two. Each string may be, for example, a sentence or a phrase.

Next, the probabilities $P(W_i)$ of occurrence of the input string of words and $P(W_c)$ of occurrence of the candidate string of words are estimated. These probabilities may be estimated empirically by examining large bodies of text, as discussed in more detail, below.

Also estimated is the probability $P(T_i/W_c)$ of misrepresenting the candidate string of words W_c as the input string of words T_i . The probability $P(T_i/W_c)$ may be chosen empirically by selecting different values until satisfactory results are obtained, as discussed in the Examples below.

After the required probabilities are estimated, the probability $P(W_i)$ is compared with the product of the probabilities $P(W_c)P(T_i/W_c)$. If $P(W_i)$ is greater than or equal to the product $P(W_c)P(T_i/W_c)$, then a first output is produced. Otherwise, a second output is produced.

As shown in FIG. 1, the first output may be the input string $W_1W_MW_N$. The second output may be the candidate string $W_2W_MW_N$.

Alternatively, the second output may be an error indication.

Two examples of the spelling error detection and correction method according to the present invention are shown in FIGS. 2 and 3. Referring to FIG. 2, the input string is a string of three words: "the horse ran". Each word in the input string of words is a member of a set of correctly spelled words. The first word $T_1 = W_2$ is "horse".

Next, the spelling of the first word "horse" is changed to form the second word W_2 , "house". The candidate string of words W_c is then "the house ran". The second word "house" is also a member of the set of correctly spelled words.

Continuing, the probability $P(W_i)$ of occurrence of the input string of words "the horse ran" is estimated to be 5×10^{-5} . The probability $P(W_c)$ of occurrence of the candidate string of words "the house ran" is estimated

to be 1×10^{-8} . While these probabilities are purely hypothetical for the purpose of illustrating the operation of the present invention, the hypothetical numbers illustrate that the probability of occurrence of "the horse ran" is much greater than the probability of occurrence of "the house ran".

Proceeding with the method, the probability $P(T_i/W_c)$ of misrepresenting the candidate string of words as the input string of words is estimated to be equal to the probability $P(T_1/W_2)$ of misspelling the second word W_2 as the first word T_1 . From experiment it has been determined that an estimate of 0.001 produces satisfactory results.

Finally, the value of $P(W_i)$ is compared to the product $P(W_c)P(T_i/W_c)$. Since the former (5×10^{-5}) is greater than the latter (1×10^{-11}), the input string of words is determined to be correct, and the candidate string of words is rejected. Accordingly, the output is "the horse ran".

FIG. 3 illustrates the operation of the spelling error detection and correction method where the input string is "the house ran". Now the first word $T_1 = W_2$ is "house", and the second word W_2 is "horse". By using the same probabilities estimated in FIG. 2, the probability of the input string (1×10^{-8}) is now less than the product of the probability of the candidate string multiplied by the probability of misrepresenting the candidate string as the input string (5×10^{-8}). Therefore, the input string is now rejected, and the candidate string is determined to be correct. The output is set to "the horse ran".

The spelling error detection and correction method according to the present invention is based on the following theory. For each candidate string of words (for example, for each candidate sentence) W_c , the probability that the candidate sentence was actually intended given that the original sentence (input string of words) $T_i = W_i$ was typed is given by

$$P(W_c|T_i) = \frac{P(W_c)P(T_i|W_c)}{P(T_i)} \quad (1)$$

In this equation, $P(T_i/W_c)$ is the probability of misrepresenting the candidate string of words W_c as the input string of words $T_i = W_i$.

The probability $P(W_i/T_i)$ that the original sentence was actually intended given that the original sentence was typed (that is, the probability of correctly spelling all of the words in the original sentence W_i) is compared to $P(W_c/T_i)$. For simplicity, both sides of the comparison are multiplied by $P(T_i)$ so that the product $P(W_i)P(T_i/W_i)$ is compared with the product $P(W_c)P(T_i/W_c)$. The sentence with the higher probability is selected as the sentence which was actually intended.

In order to further simplify the comparison, it may be assumed that the probability $P(T_i/W_i)$ of correctly spelling all of the words in the original typed sentence is equal to 1.

The probabilities $P(W_i)$ of occurrence of the input string of words and $P(W_c)$ of occurrence of the candidate string of words may be approximated by the product of n-gram probabilities for all n-grams in each string. That is, the probability of a string of words may be approximated by the product of the conditional probabilities of each word in the string, given the occurrence of the n-1 words (or absence of words) preceding each word. For example, if $n=3$, each trigram probability

may represent the probability of occurrence of the third word in the trigram, given the occurrence of the first two words in the trigram.

The conditional probabilities may be determined empirically by examining large bodies of text. For example, the conditional probability $f(W_z/W_xW_y)$ of word W_z given the occurrence of the string W_xW_y may be estimated from the equation

$$f(W_z|W_xW_y) = \lambda_1 f_1(W_z|W_xW_y) + \lambda_2 f_2(W_z|W_y) + \lambda_3 f_3(W_z) + \lambda_4 f_4 \quad (2)$$

where

$$f_1(W_z|W_xW_y) = \frac{n_{xyz}}{n_{xy}} \quad (3)$$

$$f_2(W_z|W_y) = \frac{n_{yz}}{n_y} \quad (4)$$

$$f_3(W_z) = \frac{n_z}{n} \quad (5)$$

$$f_4 = \frac{1}{n} \quad (6)$$

and

$$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1 \quad (7)$$

In equations (3)–(6), the count n_{xyz} is the number of occurrences of the trigram $W_xW_yW_z$ in a large body of training text. The count n_{xy} is the number of occurrences of the bigram W_xW_y in the training text. Similarly, n_{yz} is the number of occurrences of the bigram W_yW_z in the training text, n_y is the number of occurrences of word W_y , n_z is the number of occurrences of word W_z , and n is the total number of words in the training text. The values of the coefficients λ_1 , λ_2 , λ_3 , and λ_4 in equations (2) and (7) may be estimated by the deleted interpolation method described in an article by Lalit R. Bahl et al entitled "A Maximum Likelihood Approach to Continuous Speech Recognition" (IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-5, No. 2, March 1983, pages 179–190).

In the comparison of $P(W_i)P(T_i/W_i)$ with $P(W_c)P(T_i/W_c)$ the probability $P(T_i/W_c)$ may be approximated by the product of the probabilities of misrepresenting each word in the candidate sentence as the corresponding word in the original typed sentence. Where the original typed sentence and the candidate sentence differ by only one word $T_2=W_2$ in the original sentence and W_2 in the candidate sentence), the probability $P(T_i/W_c)$ can be estimated to be equal to the probability $P(T_2/W_2)$ of misspelling the second word as the first word.

The probability of misspelling any given word should be estimated to have a low value, for example 0.001. This value has been determined by experiment to yield satisfactory results. By increasing the probability of misspelling, the invention will find more misspellings; by decreasing the probability of misspelling, the invention will find fewer misspellings. When the word W_1 in the original typed sentence has M misspellings which result in correct dictionary entries, the probability of each misspelling becomes $(0.001/M)$ in this example.

If the probability $P(T_i/W_i)$ of correctly spelling all of the words in the original typed sentence is not estimated as 1, it may be approximated by the product of the probabilities of correctly spelling each word in the

original typed sentence. Where the original typed sentence and the candidate sentence differ by only one word, the probability $P(T_i/W_i)$ may be estimated as the probability $P(T_i/W_1)$ of correctly spelling the first word $T_1=W_1$.

FIG. 4 shows a subroutine which may be used to change the spelling of the first word W_1 to the second word W_2 . First, one or more letters in the first word W_1 are changed to form a tentative word W_T . The changes may be made by, for example, adding a letter to the first word, deleting a letter from a first word, transposing two letters in the first word, or replacing a letter in a first word.

The tentative word W_T is then compared to each word in a set of words (a spelling dictionary) L . If the tentative word W_T matches a word in the spelling dictionary L , then the second word W_2 is set equal to the tentative word.

FIG. 5 shows an alternative subroutine for changing the spelling of a word. In this routine, each word in the spelling dictionary is provided with an associated confusion group of words L_c containing M different words. For example, each word in the confusion group may have a spelling which differs from the spelling of the first word W_1 by no more than two letters. Alternatively, each word in a confusion group may be a word which sounds like and is therefore confusable with the first word (for example, "to", "two", and "too", or "principle" and "principal"). For each candidate sentence, one word is selected from the confusion group L_c as the second word W_2 .

FIG. 6 shows a modification of the spelling error detection and correction method of FIG. 1. The steps shown in FIG. 6 are intended to replace the steps in block 6 of FIG. 1.

According to the modification, the method further includes the step of estimating the probability $P(T_i/W_i)$ of correctly spelling all of the words in the input string of words $T_i=W_i$. The product of $P(W_i)P(T_i/W_i)$ is compared with the product $P(W_c)P(T_i/W_c)$. If the former is greater than or equal to the latter, a first output (for example, the input string) is produced. If the former is less than the latter, then a second output (for example, the candidate string) is produced.

An apparatus for detecting and correcting an error in an information signal, for example where each information signal represents a word having a spelling, is preferably in the form of a programmed general purpose digital computer. FIG. 7 shows an example of the organization of such an apparatus.

As shown in FIG. 7, a word processor 10 provides an input string of information signals $T_i=W_i$. Each information signal represents information, such as a word. The word processor 10 is preferably a program running on a central processor 12 which is also executing the other functions of the apparatus. However, word processor 10 may alternatively be running on its own central processor.

Under the direction of the program instructions in program instructions store 14, the central processor 12 changes a first information signal $T_1=W_1$ in the input string $T_i=W_i$ to form a second information signal W_2 representing information which is different from the information represented by the first information signal. This change forms a candidate string of information signals W_c . Under the direction of the program instructions, central processor 12 compares the second infor-

mation signal W_2 with the entries in the spelling dictionary store 16 to be sure that the second information signal is an entry in the spelling dictionary.

Having produced the input and candidate strings, central processor 12 is instructed to retrieve estimates of the probabilities of occurrence of the input and candidate strings from the word string probability store 18. The probability $P(T_i|W_c)$ of misrepresenting the information represented by the candidate string of information signals as the input string of information signals is retrieved from store 20. Finally, central processor 12 compares $P(W_i)$ with the product $P(W_c)P(T_i|W_c)$. A first output signal is sent to, for example, a display 22 if the former is greater than or equal to the latter. Otherwise, a second output signal is sent to the display 22.

W_2 is "a", and the candidate word string W_c (the candidate sentence) is "a submit that is what is happening in this case."

Table 1 shows the input and candidate sentences, the trigrams which make up each sentence, and the natural logarithms of the conditional probabilities for each trigram. The experiment was performed with four different values of the probability P_i of correctly spelling each word: $P_i=0.9999$, $P_i=0.999$, $P_i=0.99$, or $P_i=0.9$.

Since the logarithms (base e) of the probabilities are estimated in Table 1, the logarithms are added to produce estimates of the product of the probabilities.

Table 2 shows the totals obtained from Table 1. For all values of P_i , the original sentence W_i is selected over the alternative candidate sentence W_c .

TABLE 1

Input Word String ($T_i = W_i$)	Trigrams	Trigram Logarithm Probability	COMPONENTS OF $\ln P(T_i/W_i)$			
			for $P_i = 0.9999$	for $P_i = 0.999$	for $P_i = 0.99$	for $P_i = 0.9$
I	— I	-3.47634	-0.00010	-0.00100	-0.01005	-0.10536
submit	— I submit	-8.47750	-0.00010	-0.00100	-0.01005	-0.10536
that	I submit that	-1.23049	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_i) =$	-39.05735				
	$\ln P(T_i/W_i) =$		-0.0011	-0.0110	-0.1106	-1.1590
<hr/>						
Candidate Word String (W_c)	Trigrams	Trigram Logarithm Probability	COMPONENTS OF $\ln P(T_i/W_c)$			
			for $P_i = 0.9999$	for $P_i = 0.999$	for $P_i = 0.99$	for $P_i = 0.9$
a	— a	-3.96812	-9.21034	-6.90776	-4.60517	-2.30259
submit	— a submit	-10.20667	-0.00010	-0.00100	-0.01005	-0.10536
that	a submit that	-3.69384	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_c) =$	-43.74165				
	$\ln P(T_i/W_c) =$		-9.2113	-6.9178	-4.7057	-3.3562

The spelling error detection and correction method and apparatus according to the present invention were tested on 3,044 sentences which were systematically misspelled from 48 sentences. The 48 sentences were chosen from the Associated Press News Wire and from the Proceedings of the Canadian Parliament. Trigram conditional probabilities were obtained from a large corpus of text consisting primarily of office correspondence. Using a probability $P(T_i|W_i)$ of 0.999, the method selected the changed sentence 78% of the time. Of those sentences that were changed, they were changed correctly 97% of the time.

Several examples selected from the above-described tests are described below.

EXAMPLE I

In this example, the input word string (the original typed sentence) is "I submit that is what is happening in this case." The word W_1 whose spelling is being checked is "I". The word "I" has only the following simple misspelling: "a". Therefore, the second word

TABLE 2

P_i	$\ln[P(W_i)P(T_i/W_i)]$	$\ln[P(W_c)P(T_i/W_c)]$
0.99990	-39.05845	-52.95299
0.99900	-39.06836	-50.65941
0.99000	-39.16790	-48.44732
0.90000	-40.21632	-47.09784

EXAMPLE II

In this example, the input word string $T_i=W_i$ is: "I submit that is what is happening in this case". The first word $T_1=W_1$ whose spelling is being checked is "submit". The word "submit" has two simple misspellings: "summit" or "submits". In this example, the second word W_2 is selected to be "summit". Therefore, the candidate word string W_c (the candidate sentence) is "I submit that is what is happening in this case."

Table 3 shows the logarithms of the probabilities, and Table 4 provides the totals for Table 3. Again, for each

value of P_i , the original sentence is selected over the candidate.

spelling is being checked is "a". The word "a" has the following ten simple misspellings: "I", "at", "as", "an",

TABLE 3

Input Word String ($T_i = W_i$)	Trigrams	Logarithm Trigram Probability	COMPONENTS OF $\ln P(T_i/W_i)$			
			for	for	for	for
			$P_t = 0.9999$	$P_t = 0.999$	$P_t = 0.99$	$P_t = 0.9$
I	-- I	-3.47634	-0.00010	-0.00100	-0.01005	-0.10536
submit	-- I submit	-8.47750	-0.00010	-0.00100	-0.01005	-0.10536
that	I submit that	-1.23049	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_i) =$	-39.05735				
	$\ln P(T_i/W_i) =$		-0.0011	-0.0110	-0.1106	-1.1590

Candidate Word String (W_c)	Trigrams	Logarithm Trigram Probability	COMPONENTS OF $\ln P(T_i/W_c)$			
			for	for	for	for
			$P_t = 0.9999$	$P_t = 0.999$	$P_t = 0.99$	$P_t = 0.9$
I	-- I	-3.47634	-0.00010	-0.00100	-0.01005	-0.10536
submit	-- I submit	-18.48245	-9.90349	-7.60090	-5.29832	-2.99573
that	I submit that	-5.49443	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-3.50595	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_c) =$	-52.08908				
	$\ln P(T_i/W_c) =$		-9.9045	-7.6109	-5.3988	-4.0493

TABLE 4

P_t	$\ln[P(W_i)P(T_i/W_i)]$	$\ln[P(W_c)P(T_i/W_c)]$
0.99990	-39.05845	-61.99357
0.99900	-39.06836	-59.69999
0.99000	-39.16790	-57.48790
0.90000	-40.21632	-56.13842

EXAMPLE III

In this example, the input word string $T_i = W_i$ (the original typed sentence) is now "a submit that is what is happening in this case." The first word $T_1 = W_1$ whose

35 "am", "ad", "ab", "pa", "or", "ha".

A second word W_2 is selected to be "I". Therefore, the candidate string is "I submit that is what is happening in this case."

The logarithms of the individual probabilities are shown in Table 5. Note that the probability $P(T_1|W_2)$ is equal to (P_i/M) (where M equals 10.)

40 Table 6 provides the totals from Table 5. For all values of P_i , except $P_i=0.9$, the original sentence is selected over the candidate. When $P_i=0.9$, the candidate is selected over the original.

TABLE 5

Input Word String ($T_i = W_i$)	Trigrams	Logarithm Trigram Probability	COMPONENTS OF $\ln P(T_i/W_i)$			
			for	for	for	for
			$P_t = 0.9999$	$P_t = 0.999$	$P_t = 0.99$	$P_t = 0.9$
a	-- a	-3.96812	-0.00010	-0.00100	-0.01005	-0.10536
submit	-- a submit	-10.20667	-0.00010	-0.00100	-0.01005	-0.10536
that	a submit that	-3.69384	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_i) =$	-43.74165				
	$\ln P(T_i/W_i) =$		-0.0011	-0.0110	-0.1106	-1.1590

Candidate Word String (W_c)	Trigrams	Logarithm Trigram Probability	COMPONENTS OF $\ln P(T_i/W_c)$			
			for	for	for	for
			$P_t = 0.9999$	$P_t = 0.999$	$P_t = 0.99$	$P_t = 0.9$
I	-- I	-3.47634	-11.51293	-9.21034	-6.90776	-4.60317
submit	-- I submit	-8.47750	-0.00010	-0.00100	-0.01005	-0.10536

TABLE 5-continued

that	I submit that	-1.23049	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_c) =$	-39.05735				
	$\ln P(T_i/W_c) =$		-11.5139	-9.2203	-7.0083	-5.6588

TABLE 6

original typed sentence. A correction is therefore made in all cases.

TABLE 7

Input Word String ($T_i = W_i$)	Trigrams	Trigram Logarithm Probs.	COMPONENTS OF $\ln P(T_i/W_i)$			
			for $P_t = 0.9999$	for $P_t = 0.999$	for $P_t = 0.99$	for $P_t = 0.9$
I	— I	-3.47634	-0.00010	-0.00100	-0.01005	-0.10536
submit	— I submit	-18.48245	-0.00010	-0.00100	-0.01005	-0.10536
that	I submit that	-5.49443	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_i) =$	-52.08908				
	$\ln P(T_i/W_i) =$		-0.0011	-0.0110	-0.1106	-1.1590
Candidate Word String (W_c)	Trigrams	Logarithm Trigram Probability	COMPONENTS OF $\ln P(T_i/W_c)$			
			for $P_t = 0.9999$	for $P_t = 0.999$	for $P_t = 0.99$	for $P_t = 0.9$
I	— I	-3.47634	-11.51293	-9.21034	-6.90776	-4.60517
submit	— I submit	-8.47750	-0.00010	-0.00100	-0.01005	-0.10536
that	I submit that	-1.23049	-0.00010	-0.00100	-0.01005	-0.10536
is	submit that is	-4.74311	-0.00010	-0.00100	-0.01005	-0.10536
what	that is what	-3.04882	-0.00010	-0.00100	-0.01005	-0.10536
is	is what is	-3.07193	-0.00010	-0.00100	-0.01005	-0.10536
happening	what is happening	-4.88977	-0.00010	-0.00100	-0.01005	-0.10536
in	is happening in	-1.72564	-0.00010	-0.00100	-0.01005	-0.10536
this	happening in this	-3.84228	-0.00010	-0.00100	-0.01005	-0.10536
case	in this case	-2.49284	-0.00010	-0.00100	-0.01005	-0.10536
	this case.	-2.05863	-0.00010	-0.00100	-0.01005	-0.10536
	$\ln P(W_c) =$	-39.05735				
	$\ln P(T_i/W_c) =$		-9.9045	-7.6109	-5.3988	-4.0493

P_t	$\ln[P(W_i)P(T_i/W_i)]$	$\ln[P(W_c)P(T_i/W_c)]$
0.99990	-43.74275	-50.57128
0.99900	-43.75266	-48.27770
0.99000	-43.85220	-46.06561
0.90000	-44.90062	-44.71613

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TABLE 8

P_t	$\ln[P(W_i)P(T_i/W_i)]$	$\ln[P(W_c)P(T_i/W_c)]$
0.99990	-52.09018	-48.96184
0.99900	-52.10009	-46.66826
0.99000	-52.19963	-44.45617
0.90000	-53.24805	-43.10669

EXAMPLE IV

In this example, the input word string $T_i=W_i$ is "I submit that is what is happening in this case." The first word $T_1=W_1$ whose spelling is being checked is "submit". The word "submit" has two simple misspellings: "submit" or "summit".

The second word W_2 is selected to be "submit". 60 Therefore, the candidate word string W_c is "I submit that is what is happening in this case."

Table 7 shows the logarithms of the estimated probabilities of the trigrams and of correctly spelling or incorrectly spelling each word. Since $M=2$, the probability $P(T_1|W_2)=(P_t/2)$.

Table 8 provides the totals from Table 7. For all values of P_t , the candidate sentence is selected over the

We claim:

1. A spelling error detection method, said method comprising the steps of:

providing an input string of words $T_i=W_i$ produced by a word processor, each word having a spelling; changing the spelling of a first word $T_1=W_1$ in the input string to form a second word W_2 different from the first word;

replacing the first word W_1 in the input string W_i with the second word W_2 to form a candidate string of words W_c ;

estimating the probability $P(W_i)$ of occurrence of the input string of words;

estimating the probability $P(W_c)$ of occurrence of the candidate string of words;
 estimating the probability $P(T_i|W_c)$ of misrepresenting the candidate string of words W_c as the input string of words T_i ;
 comparing $P(W_i)$ with the product $P(W_c)P(T_i|W_c)$; and
 outputting the input string of words if $P(W_i)$ is greater than $P(W_c)P(T_i|W_c)$, or outputting an error indication if $P(W_i)$ is less than $P(W_c)P(T_i|W_c)$.
 2. A method as claimed in claim 1, characterized in that:
 the second output comprises the candidate string of words; and
 the probability $P(T_i|W_c)$ is estimated as the probability $P(T_1|W_2)$ of misspelling the second word W_2 as the first word T_1 .
 3. A method as claimed in claim 2, characterized in that:
 the method further comprises the step of providing a set of words, each word having a spelling;
 each word in the input string of words is a member of the set of words; and
 the second word W_2 is a member of the set of words.
 4. A method as claimed in claim 3, characterized in that:
 the method further comprises the step of estimating the probability $P(T_i|W_i)$ of correctly spelling all of the words in the input string of words W_i ;
 the step of comparing comprises comparing the product $P(W_i)P(T_i|W_i)$ with the product; and
 the step of outputting comprises outputting the first output if $P(W_i)P(T_i|W_i)$ is greater than, or outputting the second output if $P(W_i)P(T_i|W_i)$ is less than $P(W_c)P(T_i|W_c)$.
 5. A method as claimed in claim 4, characterized in that the probability $P(T_i|W_i)$ is estimated as the probability $P(T_1|W_1)$ of correctly spelling the first word T_1 .
 6. A method as claimed in claim 5, characterized in that the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 adding a letter to the first word to form a tentative word;
 comparing the tentative word to each word in the set of words; and
 using the tentative word as the second word W_2 if the tentative word matches a word in the set of words.
 7. A method as claimed in claim 5, characterized in that the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 deleting a letter from the first word to form a tentative word;
 comparing the tentative word to each word in the set of words; and
 using the tentative word as the second word W_2 if the tentative word matches a word in the set of words.
 8. A method as claimed in claim 5, characterized in that:
 the first word comprises at least two letters; and
 the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 transposing at least two letters in the first word to form a tentative word;
 comparing the tentative word to each word in the set of words; and
 using the tentative word as the second word W_2 if the tentative word matches a word in the set of words.

9. A method as claimed in claim 5, characterized in that:
 the first word comprises at least one letter; and
 the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 replacing a letter in the first word with a different letter to form a tentative word;
 comparing the tentative word to each word in the set of words; and
 using the tentative word as the second word W_2 if the tentative word matches a word in the set of words.
 10. A method as claimed in claim 5, characterized in that the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 identifying a confusion group of M different words in the set of words, each word in the confusion group having a spelling which differs from the spelling of the first word by no more than two letters; and
 selecting one word in the confusion group as the second word W_2 .
 11. A method as claimed in claim 5, characterized in that the step of changing the spelling of the first word W_1 to form the second word W_2 comprises:
 identifying a confusion group of M different words in the set of words, each word in the confusion group being confusable with the first word; and
 selecting one word in the confusion group as the second word W_2 .
 12. A method as claimed in claim 11, characterized in that:
 the probability $P(T_1|W_1)$ is estimated to be 0.999; and
 the probability $P(T_i|W_c)$ is estimated to be $(0.001/M)$.
 13. A method of detecting an error in an information signal, said method comprising the steps of:
 providing an input string of information signals $T_i=W_i$, each information signal representing information;
 changing a first information signal $T_1=W_1$ in the input string to form a second information signal W_2 representing information different from the information represented by the first information signal;
 replacing the first information signal W_1 in the input string W_i with the second information signal W_2 to form a candidate string of information signals W_c ;
 estimating the probability $P(W_i)$ of occurrence of the input string of information signals;
 estimating the probability $P(W_c)$ of occurrence of the candidate string of information signals;
 estimating the probability $P(T_i|W_c)$ of misrepresenting the information represented by the candidate string of information signals W_c as the input string of information signals T_i ;
 comparing $P(W_i)$ with the product $P(W_c)P(T_i|W_c)$; and
 outputting the input string of information signals if $P(W_i)$ is greater than $P(W_c)P(T_i|W_c)$, or outputting an error indication signal if $P(W_i)$ is less than $P(W_c)P(T_i|W_c)$.
 14. A method as claimed in claim 13, characterized in that:
 the second output signal comprises the candidate string of information signals; and
 the probability $P(T_i|W_c)$ is estimated as the probability $P(T_1|W_2)$ of misrepresenting the information represented by the second information signal W_2 as the first information signal T_1 .

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15. A method as claimed in claim 14, characterized in that:

the method further comprises the step of providing a set of words, each word having a spelling;
each information signal in the input string of information signals represents a word which is a member of the set of words; and
the second information signal W_2 represents a word which is a member of the set of words, the word represented by the second information signal being different from the word being represented by the first information signal.

16. A method as claimed in claim 15, characterized in that:

the method further comprises the step of estimating the probability $P(T_i|W_i)$ of correctly representing the information represented by all of the information signals in the input string of information signals W_i ;

the step of comparing comprises comparing the product $P(W_i)P(T_i|W_i)$ with the product $P(W_c)P(T_i|W_c)$; and

the step of outputting comprises outputting the first output signal if $P(W_i)P(T_i|W_i)$ is greater than $P(W_c)P(T_i|W_c)$, or outputting the second output signal if $P(W_i)P(T_i|W_i)$ is less than $P(W_c)P(T_i|W_c)$.

17. A method as claimed in claim 16, characterized in that: the probability $P(T_i|W_i)$ is estimated as the probability $P(T_1|W_1)$ of correctly representing the information represented by the first information signal T_1 .

18. A method as claimed in claim 17, characterized in that the step of changing the first information signal W_1 to form the second information signal W_2 comprises:

adding a letter to the word represented by the first information signal to form a tentative word;
comparing the tentative word to each word in the set of words; and
representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

19. A method as claimed in claim 17, characterized in that the step of changing the first information signal W_1 to form the second information signal W_2 comprises:

deleting a letter from the word represented by the first information signal to form a tentative word;
comparing the tentative word to each word in the set of words; and
representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

20. A method as claimed in claim 17, characterized in that:

the first information signal represents a word having at least two letters; and
the step of changing the first information signal W_1 to form the second information signal W_2 comprises: transposing at least two letters in the word represented by the first information signal to form a tentative word;
comparing the tentative word to each word in the set of words; and
representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

21. A method as claimed in claim 17, characterized in that:

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the first information signal represents a word having at least one letter; and

the step of changing the first information signal W_1 to form the second information signal W_2 comprises: replacing a letter in the word represented by the first information signal to form a tentative word;
comparing the tentative word to each word in the set of words; and
representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

22. A method as claimed in claim 17, characterized in that the step of changing the first information signal W_1 to form the second information signal W_2 comprises:

identifying a confusion group of M different words in the set of words, each word in the confusion group having a spelling which differs from the spelling of the word represented by the first information signal by no more than two letters; and
representing one word in the confusion group as the second information signal W_2 .

23. A method as claimed in claim 17, characterized in that the step of changing the first information signal W_1 to form the second information signal W_2 comprises:

identifying a confusion group of M different words in the set of words, each word in the confusion group being confusable with the word represented by the first information signal; and
representing one word in the confusion group as the second information signal W_2 .

24. A method as claimed in claim 23, characterized in that:

the probability $P(T_1|W_1)$ is estimated to be 0.999; and
the probability $P(T_i|W_c)$ is estimated to be $(0.001/M)$.

25. An apparatus for detecting an error in an information signal, said apparatus comprising:

means for providing an input string of information signals $T_i=W_i$, each information signal representing information;

means for changing a first information signal $T_1=W_1$ in the input string to form a second information signal W_2 representing information different from the information represented by the first information signal;

means for replacing the first information signal W_1 in the input string with the second information signal W_2 to form a candidate string of information signals W_c ;

means for estimating the probability $P(W_i)$ of occurrence of the input string of information signals;

means for estimating the probability $P(W_c)$ of occurrence of the candidate string of information signals;

means for estimating the probability $P(T_i|W_c)$ of misrepresenting the information represented by the candidate string of information signals W_c as the input string of information signals T_i ;

means for comparing $P(W_i)$ with the product $P(W_c)P(T_i|W_c)$; and

means for outputting the input string of information signals if $P(W_i)$ is greater than $P(W_c)P(T_i|W_c)$, or outputting an error indication signal if $P(W_i)$ is less than $P(W_c)P(T_i|W_c)$.

26. An apparatus as claimed in claim 25, characterized in that:

the second output signal comprises the candidate string of information signals; and

the probability $P(T_i|W_c)$ is estimated as the probability $P(T_1|W_2)$ of misrepresenting the information represented by the second information signal W_2 as the first information signal T_1 .

27. An apparatus as claimed in claim 26, characterized in that:

the apparatus further comprises dictionary means for storing a set of words, each word having a spelling; each information signal in the input string of information signals represents a word which is a member of the set of words; and

the second information signal W_2 represents a word which is a member of the set of words, the word represented by the second information signal being different from the word being represented by the first information signal.

28. An apparatus as claimed in claim 27, characterized in that:

the apparatus further comprises means for estimating the probability $P(T_i|W_i)$ of correctly representing all of the information represented by the input string of information signals W_i ;

the means for comparing comprises means for comparing the product $P(W_i)P(T_i|W_i)$ with the product $P(W_c)P(T_i|W_c)$; and

the means for outputting comprises means for outputting the first output signal if $P(W_i)P(T_i|W_i)$ is greater than $P(W_c)P(T_i|W_c)$, or outputting the second output signal if $P(W_i)P(T_i|W_i)$ is less than $P(W_c)P(T_i|W_c)$.

29. An apparatus as claimed in claim 28, characterized in that: the probability $P(T_i|W_i)$ is estimated as the probability $P(T_1|W_1)$ of correctly representing the information represented by the first information signal W_1 .

30. An apparatus as claimed in claim 29, characterized in that the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for adding a letter to the word represented by the first information signal to form a tentative word;

means for comparing the tentative word to each word in the set of words; and

means for representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

31. An apparatus as claimed in claim 29, characterized in that the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for deleting a letter from the word represented by the first information signal to form a tentative word;

means for comparing the tentative word to each word in the set of words; and

means for representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

32. An apparatus as claimed in claim 27, characterized in that

the first information signal represents a word having at least two letters; and

the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for transporting at least two letters in the word represented by the first information signal to form a tentative word;

means for comparing the tentative word to each word in the set of words; and

means for representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

33. An apparatus as claimed in claim 29, characterized in that:

the first information signal represents a word having at least one letter; and

the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for replacing a letter in the word represented by the first information signal to form a tentative word;

means for comparing the tentative word to each word in the set of words; and

means for representing the tentative word as the second information signal W_2 if the tentative word matches a word in the set of words.

34. An apparatus as claimed in claim 29, characterized in that the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for identifying a confusion group of M different words in the set of words, each word in the confusion group having a spelling which differs from the spelling of the word represented by the first information signal by no more than two letters; and

means for representing one word in the confusion group as the second information signal W_2 .

35. An apparatus as claimed in claim 29, characterized in that the means for changing the first information signal W_1 to form the second information signal W_2 comprises:

means for identifying a confusion group of M different words in the set of words, each word in the confusion group being confusable with the word represented by the first information signal; and means for representing one word in the confusion group as the second information signal W_2 .

36. A method as claimed in claim 35, characterized in that:

the probability $P(T_1|W_1)$ is estimated to be 0.999; and the probability $P(T_i|W_c)$ is estimated to be $(0.001/M)$.

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